CHAPTER 8

DEVELOPMENTS AND INTERSECTIONS

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Describe sheet metal developments.*

- *Explain the differences among parallel, radial, and triangulation developments.*

Sheet metal drawings are also known as sheet metal developments a pattern drawings, and we may use all three terms in this chapter. This is true because the layout, when made on heavy cardboard thin metal, a wood, is often used as a pattern to trace the developed shape on flat material. These drawings are used to construct various sheet metal items, such as ducts for heating, ventilation, and air-conditioning systems; flashing, valleys, and downspouts in buildings; and parts on boats, ships, and aircraft.

A sheet metal development serves to open up an object that has been rolled, folded, or a combination of both, and makes that object appear to be spread out on a plane or flat surface. Sheet metal layout drawings are based on three types of development: parallel, radial, and triangulation. We will discuss each of these, but first we will look at the drawings of corrections used to join sheet metal objects.

JOINTS, SEAMS, AND EDGES

A development of an object that will be made of thin metal, such as a duct or part of an aircraft skin, must include consideration of the developed surfaces, the joining of the edges of these surfaces, and exposed edges. The drawing must allow for the additional material needed for those joints, seams, and edges.

Figure 8-1 shows various ways to illustrate seams, and edges. Seams are used to join edges. The seams may be fastened together by lock seams, solder, rivets, adhesive, or welds. Exposed edges are folded or wired to give the edges added strength and to eliminate sharp edges.

The lap seam shown is the least difficult. The pieces of stock are merely lapped one over the other, as shown in view C, and secured either by riveting, soldering, spot welding, or by all three methods, depending on the nature of the job. A flat lock seam (view C) is used to construct cylindrical objects, such as funnels, pipe sections, and containers.

Note that most of the sheet metal developments illustrated in this chapter do not make any allowances for edges, joints, or seams. However, the draftsman who lays out a development must add extra metal where needed

BENDS

The drafter must also show where the material will be bent, and figure 8-2 shows several methods used to mark bend lines. If the finished part is not shown with the development, then drawing instructions, such as *bend up 90 degrees, bend down 180 degrees, and bend up 45 degrees,* should be shown beside each bend line.

Anyone who bends metal to exact dimensions must know the bend allowance, which is the amount of material used to form the bend. Bending compresses the metal on the inside of the bend and stretches the metal on its outside. About halfway between these two extremes lies a space that neither shrinks nor stretches; it is known as the neutral line or neutral axis, as shown in figure 8-3. Bend allowance is computed along this axis.

You should understand the terms used to explain bend allowance. These terms are illustrated in figure 8-4 and defined in the following paragraphs:

LEG—The longer part of a formed angle.

FLANGE—The shorter part of a formed angle. If both parts are the same length, each is called a leg.

MOLD LINE (ML)—The line formed by extending the outside surfaces of the leg and flange so they intersect. It is the imaginary point from which base measurements are shown on drawings.

BEND TANGENT LINE (BL)—The line at which the metal starts to bend.

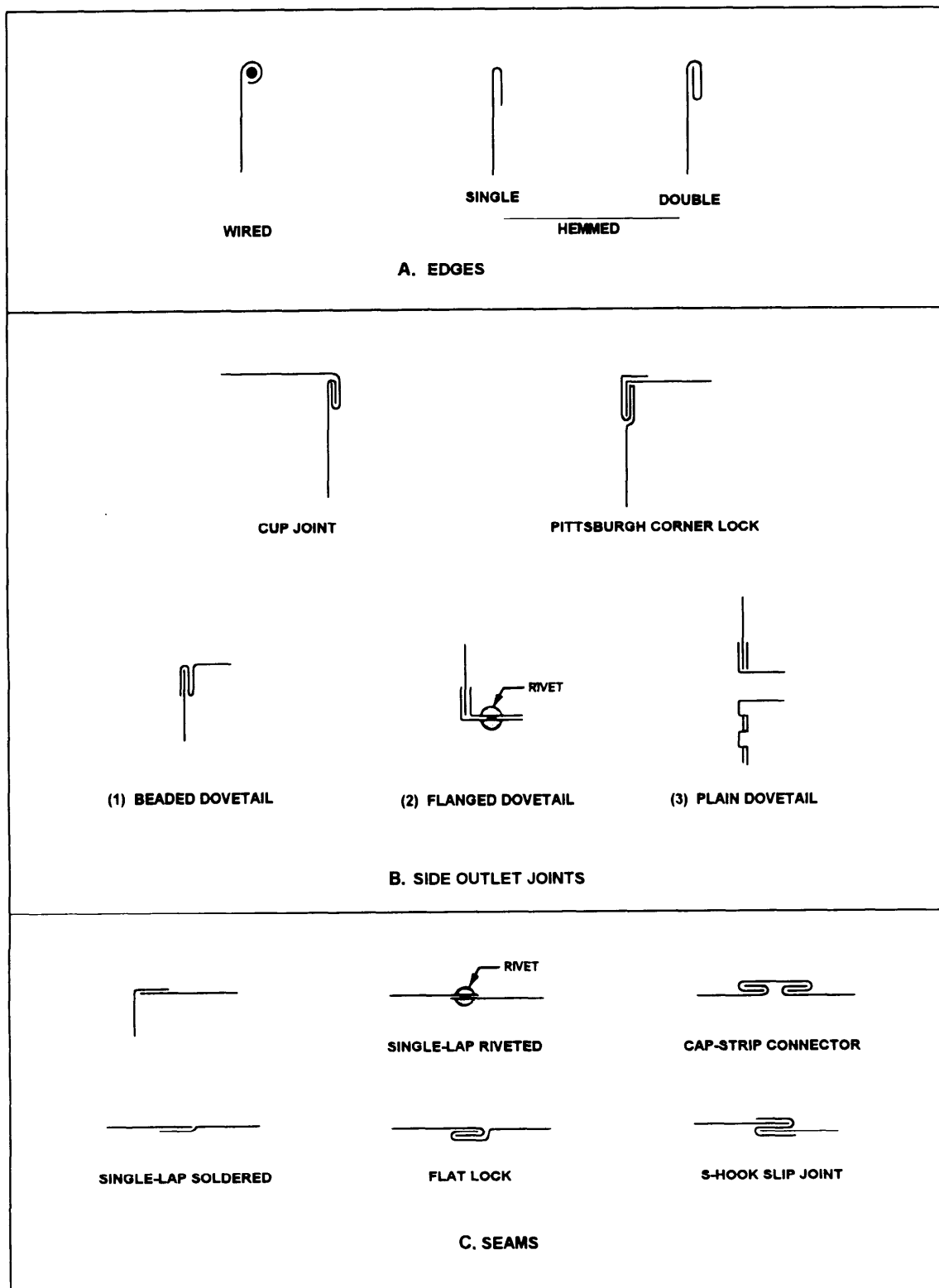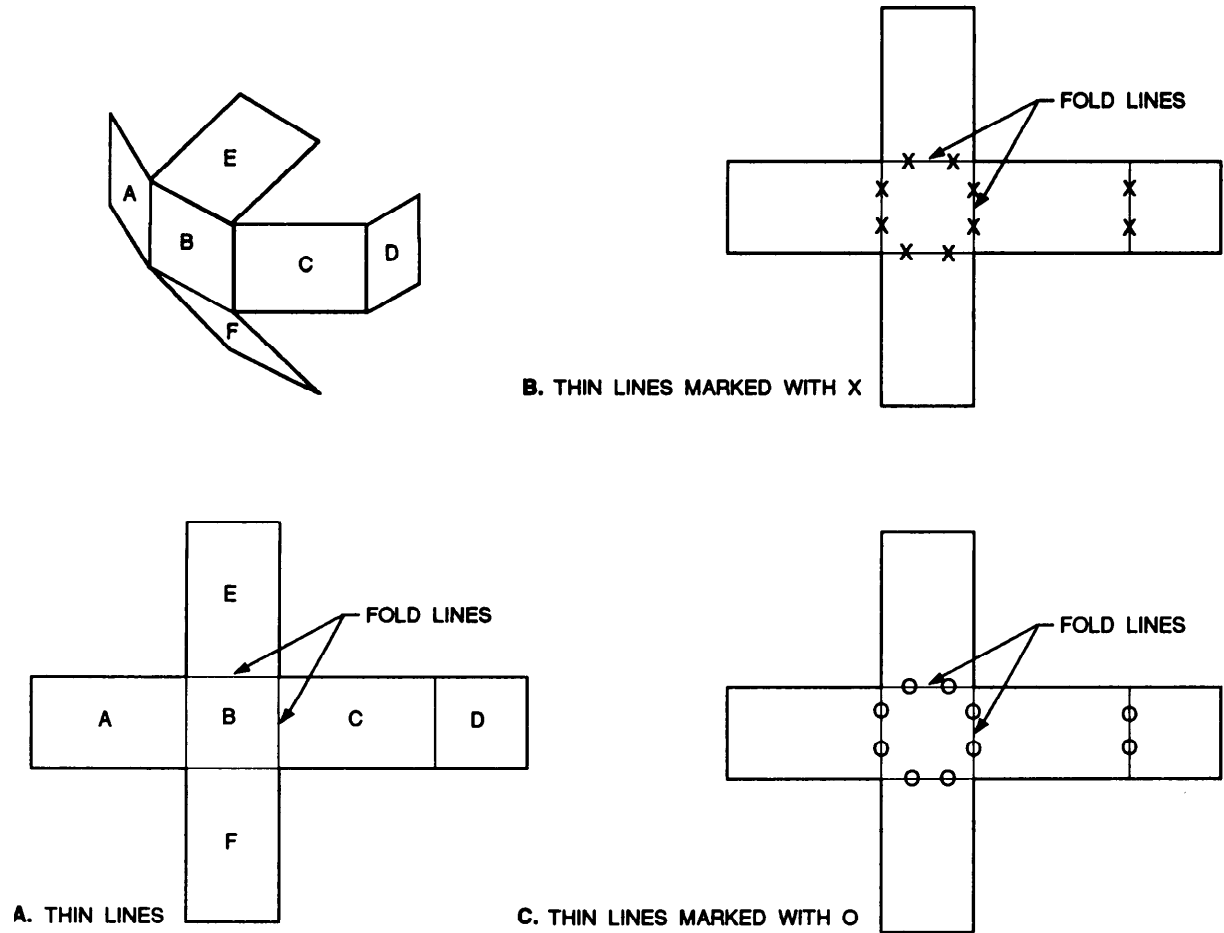BEND ALLIANCE (BA)—The amount of metal used to make the bend.

WIRED

SINGLE   DOUBLE

HEMMED

A. EDGES

CUP JOINT

PITTSBURGH CORNER LOCK

(1) BEADED DOVETAIL

RIVET

(2) FLANGED DOVETAIL

(3) PLAIN DOVETAIL

B. SIDE OUTLET JOINTS

RIVET

SINGLE-LAP RIVETED

CAP-STRIP CONNECTOR

SINGLE-LAP SOLDERED

FLAT LOCK

S-HOOK SLIP JOINT

C. SEAMS

Figure 8-1.—Joints, seams, and edges

B. THIN LINES MARKED WITH X

A. THIN LINES

C. THIN LINES MARKED WITH O

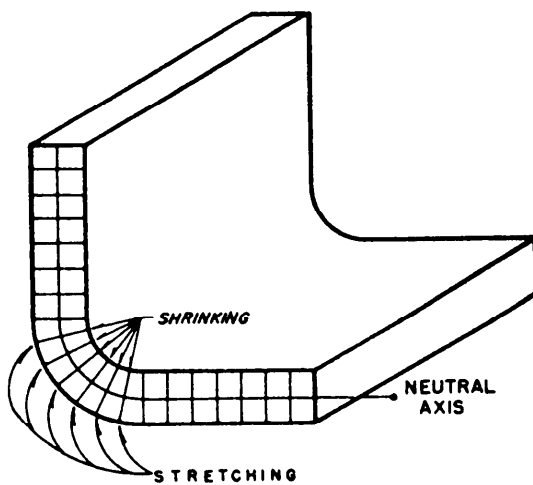Figure 8-2.—Methods used to identify fold or bend lines

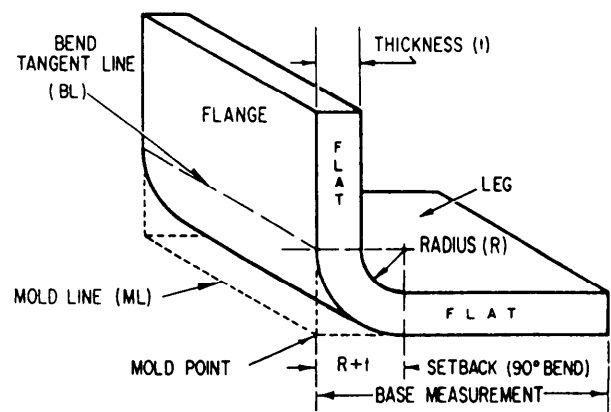Figure 8-3.—Bend characteristics.

Figure 8-4.—Bend allowance terms.

RADIUS (R)—The radius of the bend. It is always measured from the inside of the bend unless stated otherwise.

SETBACK (SB)—The distance from the bend tangent line to the mold point. In a 90-degree bend, SB = R + T (radius of bend plus thickness of metal).

FLAT—That portion not including the bend. It is equal to the base measurement minus the setback.

BASE MEASUREMENT—The outside diameter of the formed part.

Engineers have found they can get accurate bends by using the following formula:

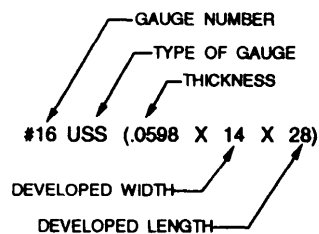$$BA = N \times 0.01743 \times R + 0.0078 \times T$$

Figure 8-5.—Reading sheet metal sizes.

Where BA = bend allowance, N = number of degrees of bend, R = the desired bend radius, and T = the thickness of the metal.

SHEET METAL SIZES

Metal thicknesses up to 0.25 inch (6mm) are usually designated by a series of gauge numbers. Figure 8-5 shows how to read them. Metal 0.25 inch and over is given in inch and millimeter sizes. In calling for the material size of sheet metal developments, it is customary to give the gauge number, type of gauge, and its inch or millimeter equivalent in brackets followed by the developed width and length (fig. 8-5).

TYPES OF DEVELOPMENT

A surface is said to be developable if a thin sheet of flexible material, such as paper, can be wrapped smoothly about its surface. Therefore, objects that have plane, flat, or single-curved surfaces are developable. But a surface that is double-curved or warped is not considered developable, and approximate methods must be used to develop it.
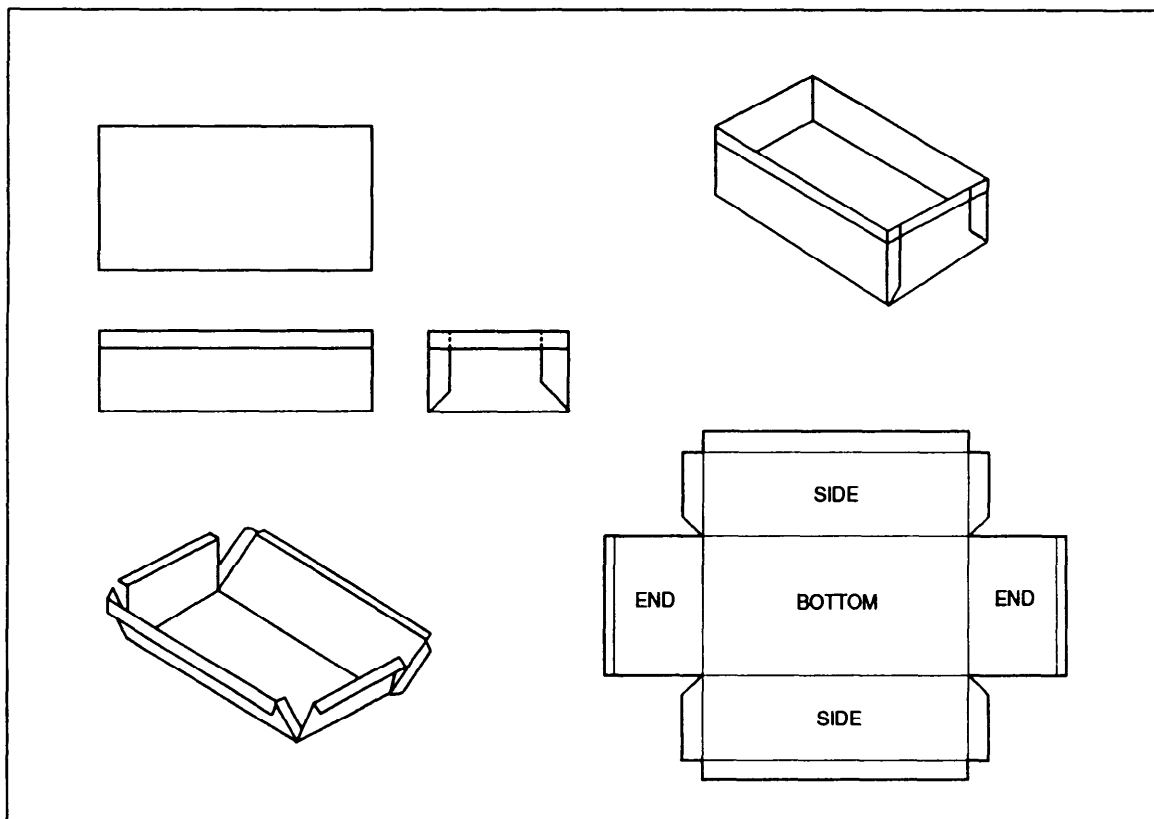

Figure 8-6.—Development of a rectangular box.

A spherical shape would be an example of an approximate development. The material would be stretched to compensate for small inaccuracies. For example, the coverings for a football or basketball are made in segments. Each segment is cut to an approximate developed shape, and the segments are then stretched and sewed together to give the desired shape.

The following pages cover developable and nondevelopable, or approximate, methods. For examples, straight-line and radial-line development are developable forms. However, triangular development requires approximation.

STRAIGHT-LINE DEVELOPMENT

This term refers to the development of an object that has surfaces on a flat plane of projection. The true size of each side of the object is known and the sides can be laid out in successive order. Figure 8-6 shows the development of a simple rectangular box with a bottom and four sides. There is an allowance for lap seams at the corners and for a folded edge. The fold lines are shown as thin unbroken lines. Note that all lines for each surface are straight.

Figure 8-7 shows a development drawing with a complete set of folding instructions. Figure 8-8 shows a letter box development drawing where the back is higher than the front surface.

RADIAL-LINE DEVELOPMENT

In radial-line development, the slanting lines of pyramids and cones do not always appear in their true lengths in an orthographic view. The draftsman must find other means, as we will discuss in the following paragraphs on the development of right, oblique, and truncated pyramids.
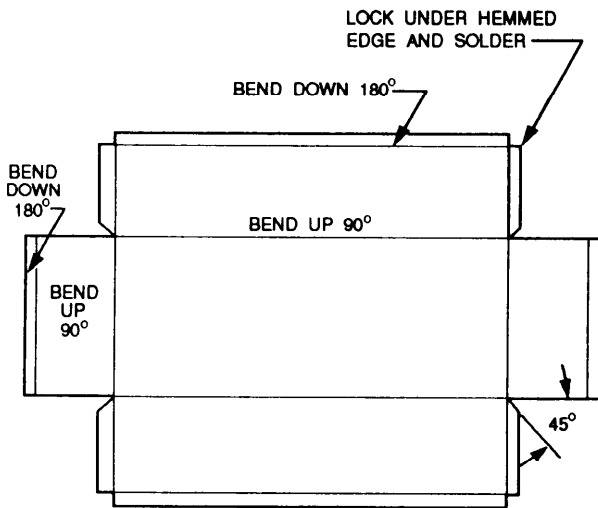

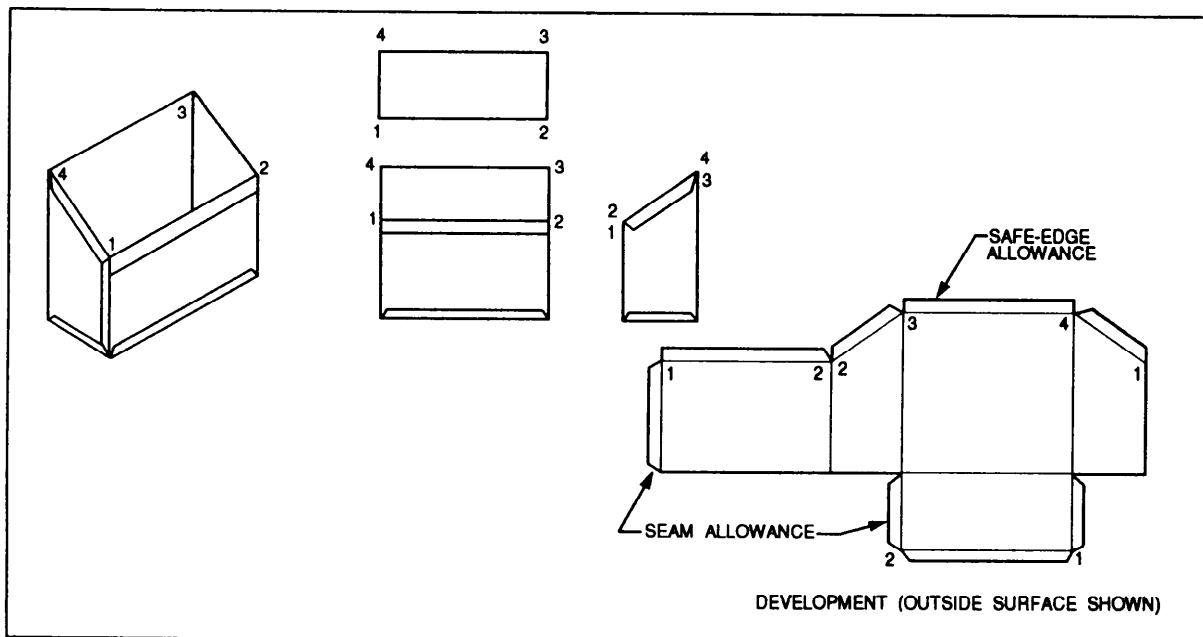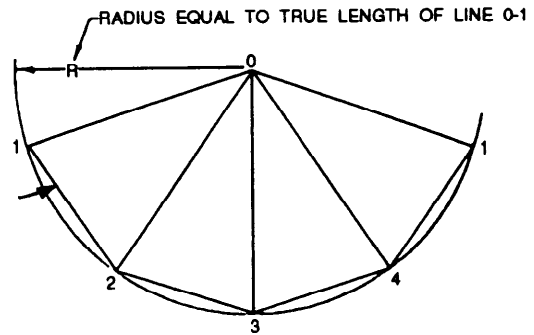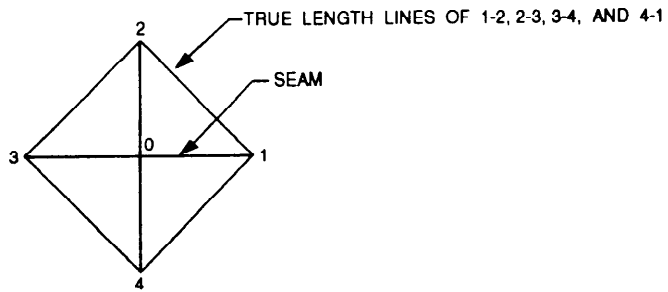**Figure 8-7.—Development drawing with folding instructions.**

DEVELOPMENT (OUTSIDE SURFACE SHOWN)

Figure 8-8.—Development drawing of a letter box.

TRUE LENGTH LINES OF 1-2, 2-3, 3-4, AND 4-1

SEAM

TRUE LENGTH OF LINES
0-1, 0-2, 0-3, AND 0-4

LINES 0-2 AND 0-4 ARE
DISTORTED ON THIS VIEW

RADIUS EQUAL TO TRUE LENGTH OF LINE 0-1

A. DEVELOPMENT OF A PYRAMID

RADIUS EQUAL TO
DISTANCE AC ON
FRONT VIEW

RADIUS EQUAL TO TRUE
LENGTH OF LINE 0-1

RADIUS EQUAL TO
DISTANCE BD
ON TOP VIEW

LINE E-1 TRUE
LENGTH OF LINES
B-2, AND D-4

TRUE LENGTH OF
LINES 0-1, 0-2, 0-3,
AND 0-4

TRUE
LENGTH OF
LINE C-3

TRUE LENGTH OF
LINE A-1
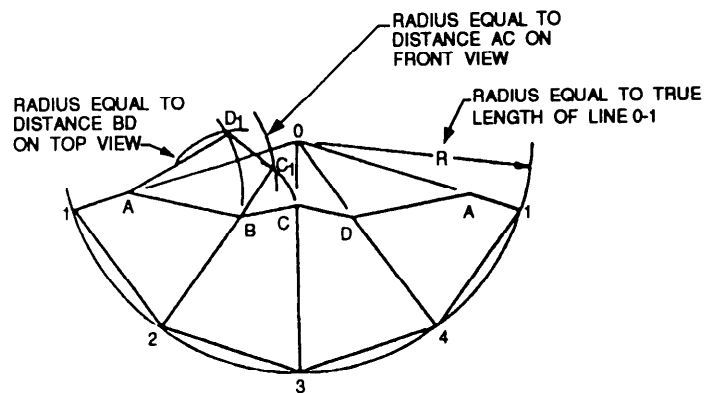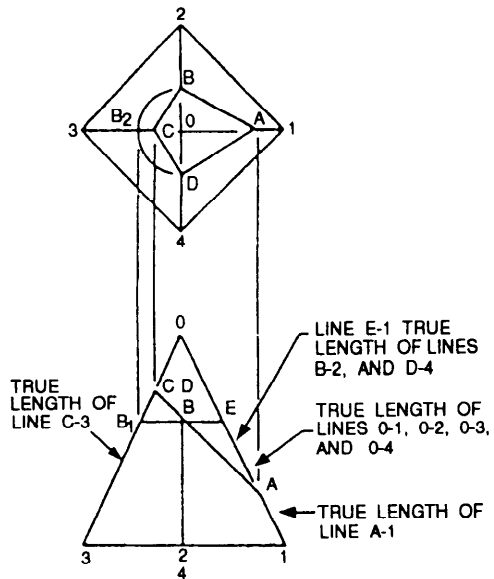
B. DEVELOPMENT OF A TRUNCATED PYRAMID

Figure 8-9.—Development of a right pyramid with true length-of-edge lines shown.
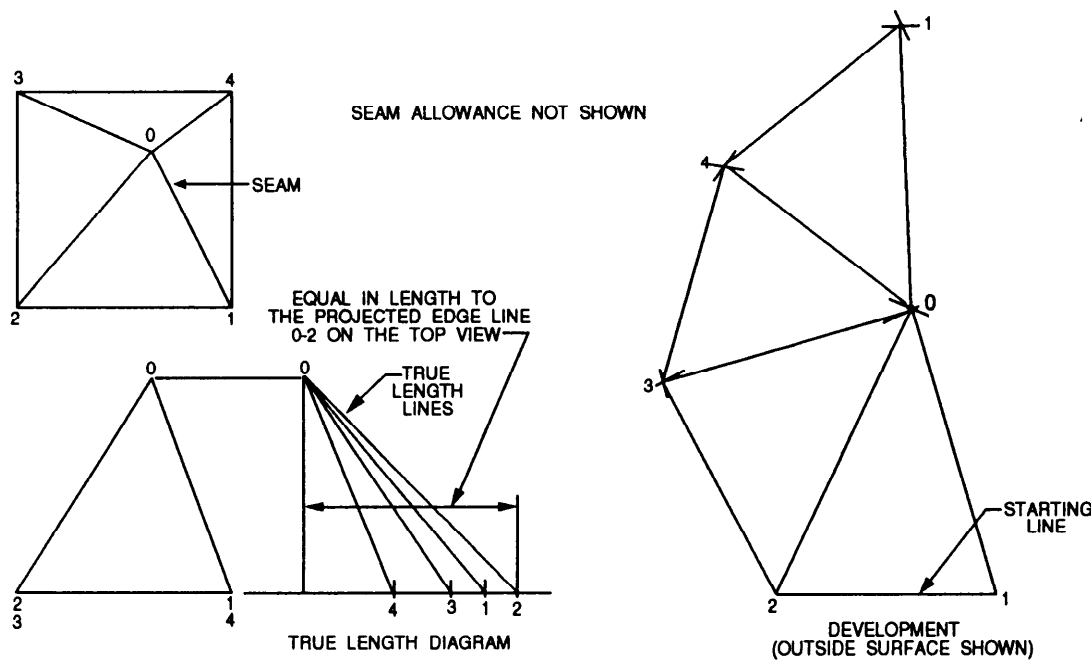
Figure 8-10.—Development of an oblique pyramid by triangulation.

Right Pyramid

Construct a radial-line development of a triangle with a true length-of-edge line (fig. 8-9) and a right pyramid having all the lateral edges (from vertex to the base) of equal length. Since the true length of the lateral edges is shown in the front view (line (0-1 or 0-3) and the top view shows the true lengths of the edges of the base (lines 1-2, 2-3, and so on), the development may be constructed as follows:

With 0 as center (corresponding to the apex) and with a radius equal to the true length of the lateral edges (line 0-1 in the front view), draw an arc as shown. Drop a perpendicular line from 0 to intersect the arc at point 3. With a radius equal to the length of the edge of the base (line 1-2 on the top view), start at point 3 and step off the distances 3-2, 2-1, 3-4, and 4-1 on the large arc. Join these points with straight lines. Then connect the points to point 0 by a straight line to complete the development. Lines 0-2, 0-3, and 0-4 are the fold lines on which the development is folded to shape the pyramid The base and seam allowance have been omitted for clarity.

Oblique Pyramid

The oblique pyramid in figure 8-10 has all its lateral edges of unequal length. The true length of each of these edges must first be found as shown in the true-length diagram. The development may now be constructed as follows:

Lay out base line 1-2 in the development view equal in length to base line 1-2 found in the top view. With point 1 as center and a radius equal in length to line 0-1 in the true diagram, swing an arc. With point 2 as center and a radius equal in length to line 0-2 in the true-length diagram, swing an arc intersecting the first arc at 0. With point 0 as center and a radius equal in length to line 0-3 in the true-length diagram, swing an arc. With point 2 as center and radius equal in length to base line 2-3 found in the top view, swing an arc intersecting the first arc at point 3. Locate points 4 and 1 in a similar manner, and join those points, as shown, with straight lines. The base and seam lines have been omitted on the development drawing.

Truncated Pyramid

Figure 8-11 shows a truncated pyramid that is developed in the following manner: Look at the views in figure 8-11 as you read the explanation.

Draw the orthographic views, extending the lines of the sides to the apex at the top in view A. Draw three horizontal construction lines on the right side of the orthographic view (view B), one from the center of the top view; one from the top of the front view; and one from the bottom of the front view. With the point of the compass in the center of the top view, scribe two arcs (view C). Draw one from the inside corner of the top view to the horizontal line (point W), and the other from the outside corner of the top view to the horizontal line (point X). Draw two vertical lines, one from point W in
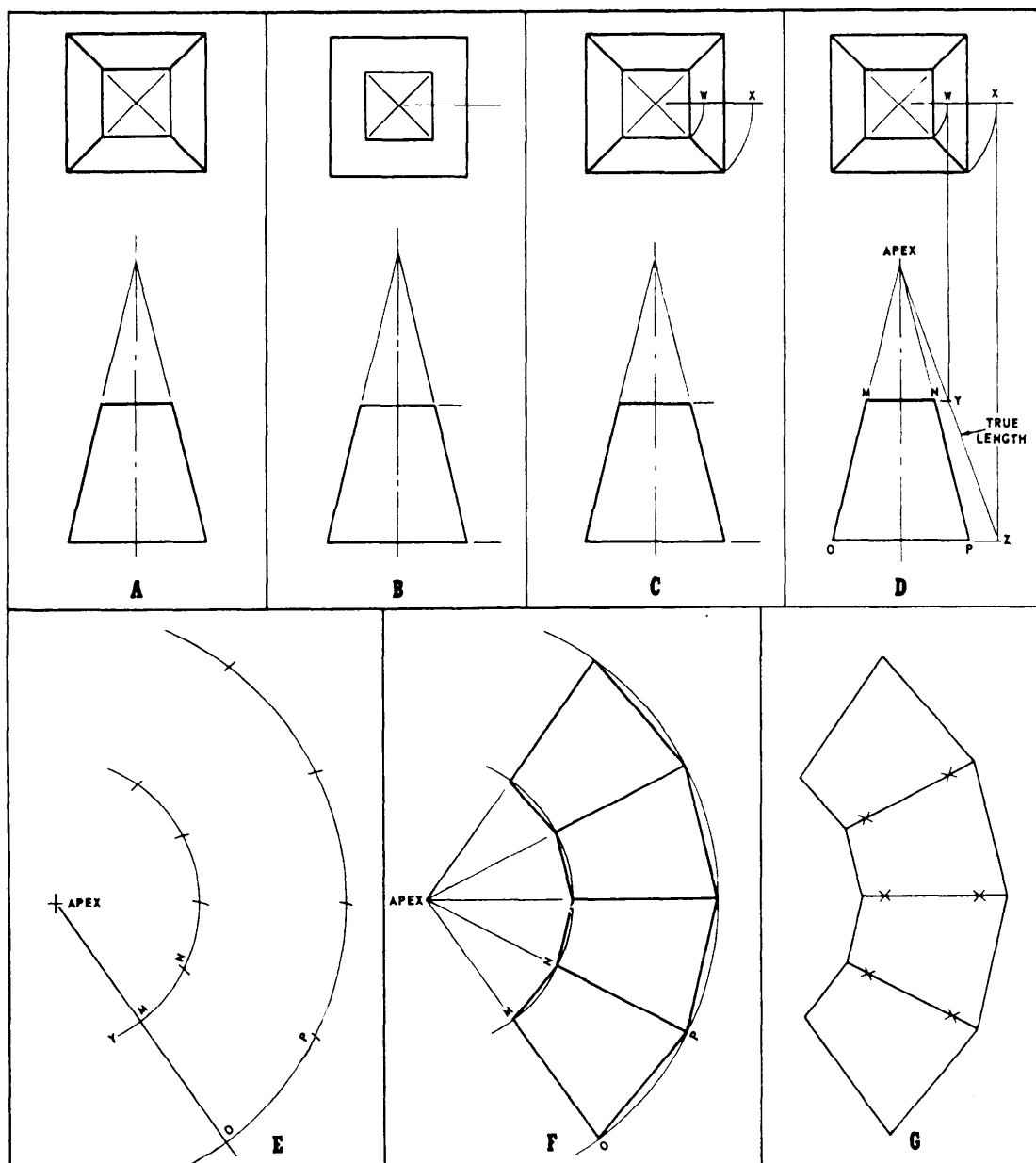
Figure 8-11.—Development of a truncated pyramid.

view D to the upper horizontal line on the front view (point Y), and the other from X to the lower horizontal line of the front view (point 2). Draw a line from the apex through points Y and 2 in view D. The distance between points Y and Z equals the true length of the truncated pyramid With the compass point at the apex of view E, find any convenient point to the right of the orthographic view, scribe an arc with a radius equal to the distance between the apex and point Y in view D, and a second arc with a radius equal to the distance between the apex and point Z in view D. The two arcs are shown in view E. Draw a radial line beginning at the apex and cutting across arcs Y and Z in view E. Step off lengths along these arcs equal to the length of the sides of the pyramid: MN for the inside arc and OP for

the outside arc (view E); the lengths MN and OP are taken from the orthographic view in view D. Connect the points along each arc with heavy lines (for example, points MN along the inner arc and points OP along the outer arc); Also use light lines to connect the apex with points M and 0, and the apex with points N and P, and so on, as shown in view F.

View G is the completed stretchout of a truncated pyramid complete with bend lines, which are marked (X).

PARALLEL-LINE DEVELOPMENT

Look at figure 8-12 as you read the following material on parallel-line development.
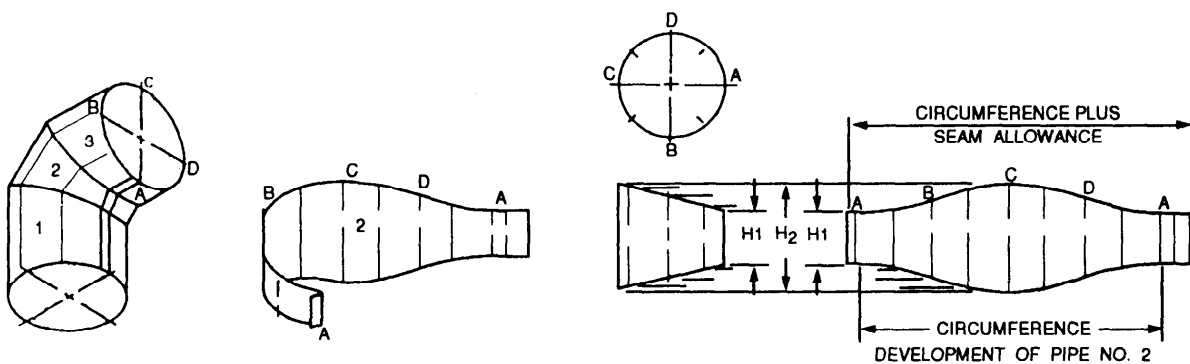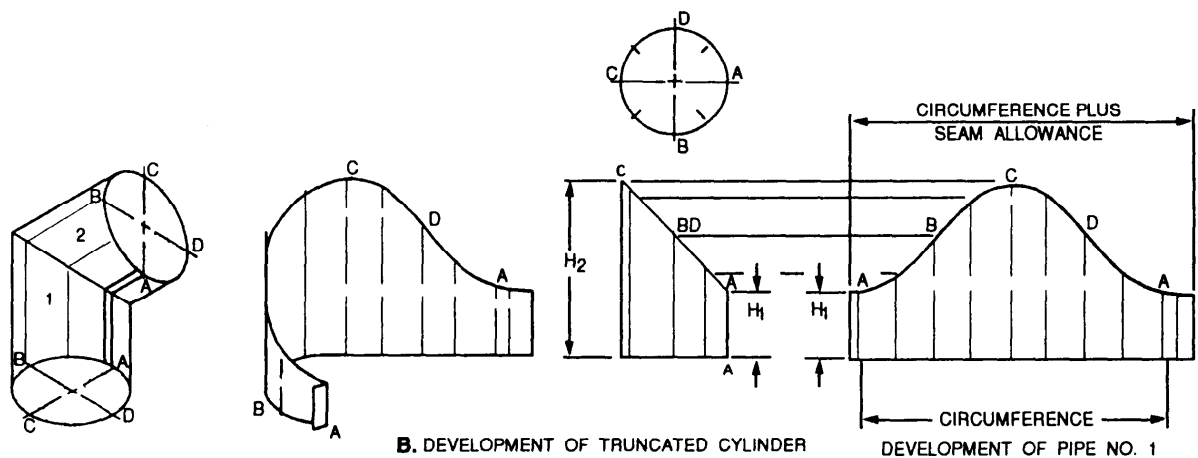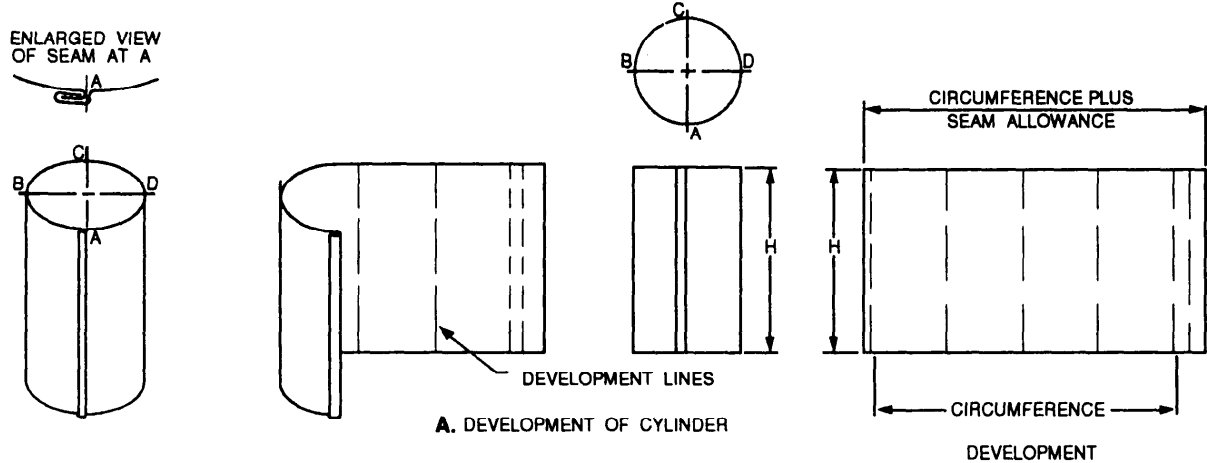
ENLARGED VIEW
OF SEAM AT A

DEVELOPMENT LINES

A. DEVELOPMENT OF CYLINDER

CIRCUMFERENCE PLUS
SEAM ALLOWANCE

H

CIRCUMFERENCE

DEVELOPMENT

B. DEVELOPMENT OF TRUNCATED CYLINDER

CIRCUMFERENCE PLUS
SEAM ALLOWANCE

H_2

H_1

H_1

CIRCUMFERENCE

DEVELOPMENT OF PIPE NO. 1

CIRCUMFERENCE PLUS
SEAM ALLOWANCE

H_1 H_2 H_1

CIRCUMFERENCE
DEVELOPMENT OF PIPE NO. 2

C. DEVELOPMENT OF A CYLINDER WITH THE TOP AND BOTTOM TRUNCATED

Figure 8-12.—Development of cylinders.

8-9

A. DEVELOPMENT OF A 2-PIECE ELBOW WITH BOTH SEAMS ON LINE A

B. DEVELOPMENT OF A 2-PIECE ELBOW WITH SEAMS ON LINES A AND C

C. DEVELOPMENT OF A 3-PIECE ELBOW WITH SEAMS ALTERNATED ON LINES A AND C
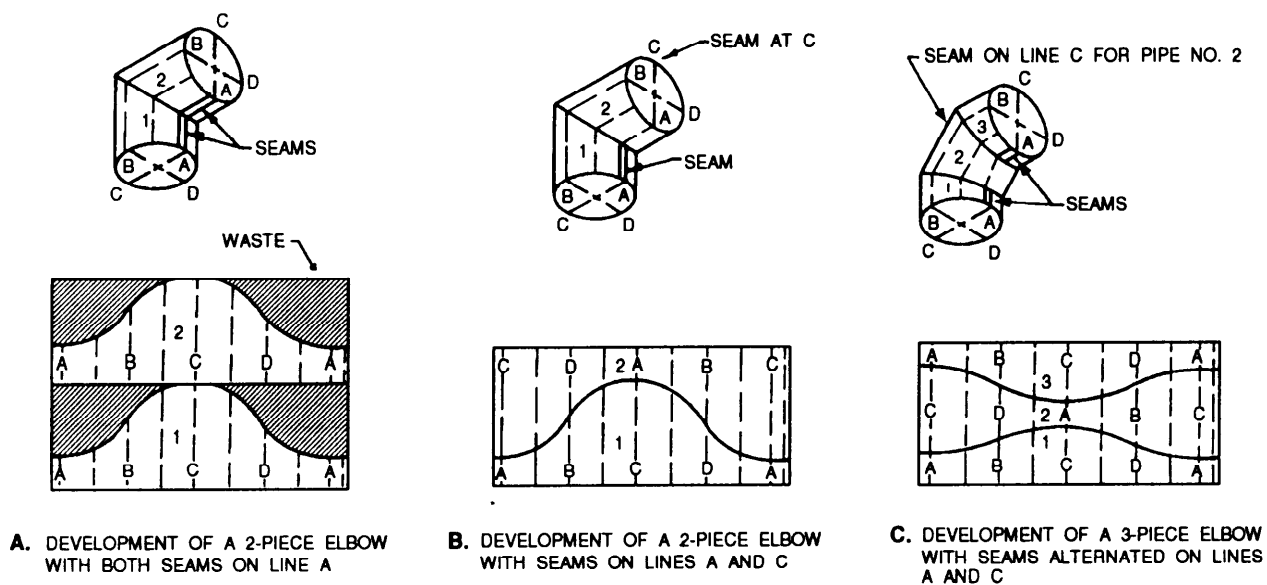
Figure 8-13.—Location of seams on elbows.

A. PROPORTION OF HEIGHT TO BASE

DEVELOPMENT

B. DEVELOPMENT PROCEDURE
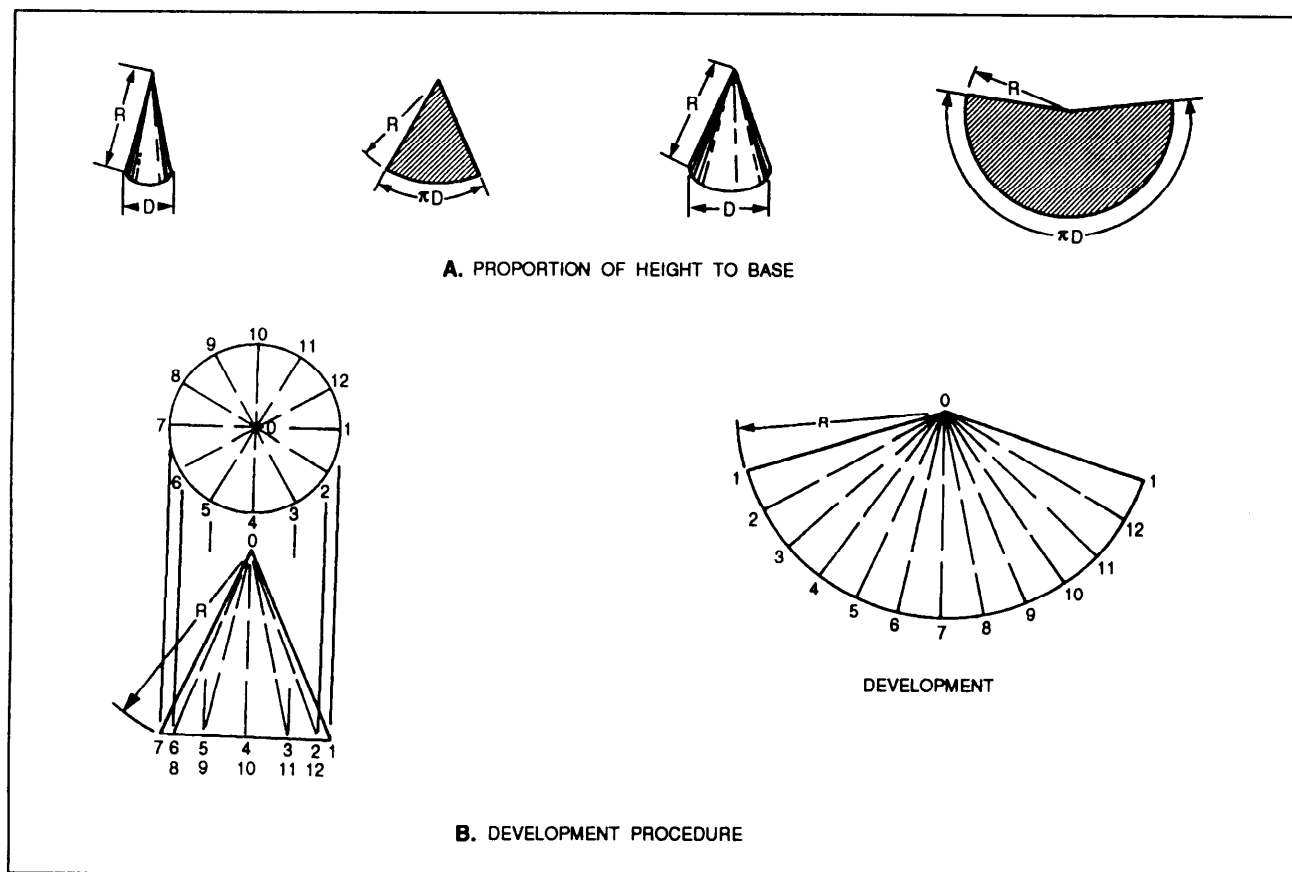
Figure 8-14.—Development of a cone.

8-10

View A shows the lateral, or curved, surface of a cylindrically shaped object, such as a tin can. It is developable since it has a single-curved surface of one constant radius. The width of the development is equal to the height of the cylinder, and the length of the development is equal to the circumference of the cylinder plus the seam allowance.

View B shows the development of a cylinder with the top truncated at a 45-degree angle (one half of a two-piece 90-degree elbow). Points of intersection are established to give the curved shape on the development. These points are derived from the intersection of a length location, representing a certain distance around the circumference from a starting point, and the height location at that same point on the circumference. The closer the points of intersection are to one another, the greater the accuracy of the development. An irregular curve is used to connect the points of intersection.

View C, shows the development of the surface of a cylinder with both the top and bottom truncated at an angle of 22.5° (the center part of a three-piece elbow). It is normal practice in sheet metal work to place the seam on the shortest side. In the development of elbows, however, the practice would result in considerable waste of material, as shown in view A. To avoid this waste and to simplify cutting the pieces, the seams are alternately placed 180° apart, as shown in figure 8-13, view B, for a two-piece elbow, and view C for a three-piece elbow.

RADIAL-LINE DEVELOPMENT OF CONICAL SURFACES

The surface of a cone is developable because a thin sheet of flexible material can be wrapped smoothly about it. The two dimensions necessary to make the development of the surface are the slant height of the cone and the circumference of its base. For a right circular cone (symmetrical about the vertical axis), the developed shape is a sector of a circle. The radius for this sector is the slant height of the cone, and the length around the perimeter of the sector is equal to the circumference of the base. The proportion of the height to the base diameter determines the size of the sector, as shown in figure 8-14, view A.

The next three subjects deal with the development of a regular cone, a truncated cone, and an oblique cone.

Regular Cone

In figure 8-14, view B, the top view is divided into an equal number of divisions, in this case 12. The chordal distance between these points is used to step off the length of arc on the development. The radius for the development is seen as the slant height in the front view. If a cone is truncated at an angle to the base, the inside shape on the development no longer has a constant radius; it is an ellipse that must be plotted by establishing points of intersection. The divisions made on the top view are projected down to the base of the cone in the front view. Element lines are drawn from these points to the apex of the cone. These element lines are seen in their true length only when the viewer is looking at right angles to them. Thus the points at which they cross the truncation line must be carried across, parallel to the base, to the outside element line, which is seen in its true length. The development is first made to represent the complete surface of the cone. Element lines are drawn from the step-off points about the circumference to the center point. True-length settings for each element line are taken for the front view and marked off on the corresponding element lines in the development. An irregular curve is used to connect these points of intersection, giving the proper inside shape.

Truncated Cone

The development of a frustum of a cone is the development of a full cone less the development of the part removed, as shown in figure 8-15. Note that, at all times, the radius setting, either R_1 or R_2, is a slant height, a distance taken on the surface of the cones.

When the top of a cone is truncated at an angle to the base, the top surface will not be seen as a true circle. This shape must be plotted by established points of intersection. True radius settings for each element line are taken from the front view and marked off on the corresponding element line in the top view. These points are connected with an irregular curve to give the correct oval shape for the top surface. If the development of the sloping top surface is required, an auxiliary view of this surface shows its true shape.

Oblique Cone

An oblique cone is generally developed by the triangulation method. Look at figure 8-16 as you read this explanation. The base of the cone is divided into an equal number of divisions, and elements 0-1, 0-2, and so on are drawn in the top view, projected down, and drawn in the front view. The true lengths of the elements
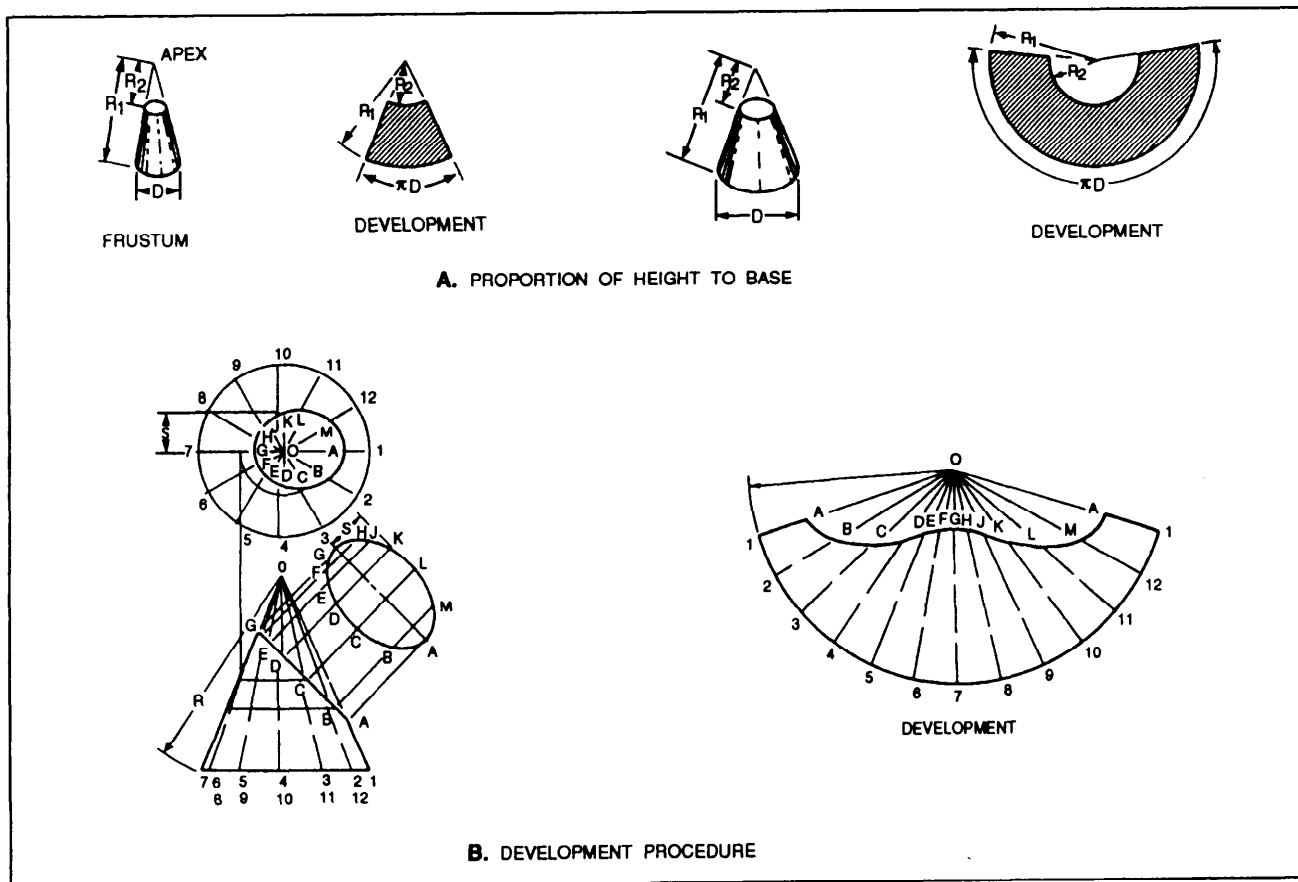
A. PROPORTION OF HEIGHT TO BASE

B. DEVELOPMENT PROCEDURE

Figure 8-15.—Development of a truncated cone.

TRUE LENGTH OF ELEMENTS

ELEMENTS

SEAM

TRUE LENGTH DIAGRAM

STARTING LINE

EQUAL IN LENGTH TO ELEMENT
LINES 0-6 AND 0-8 IN TOP VIEW

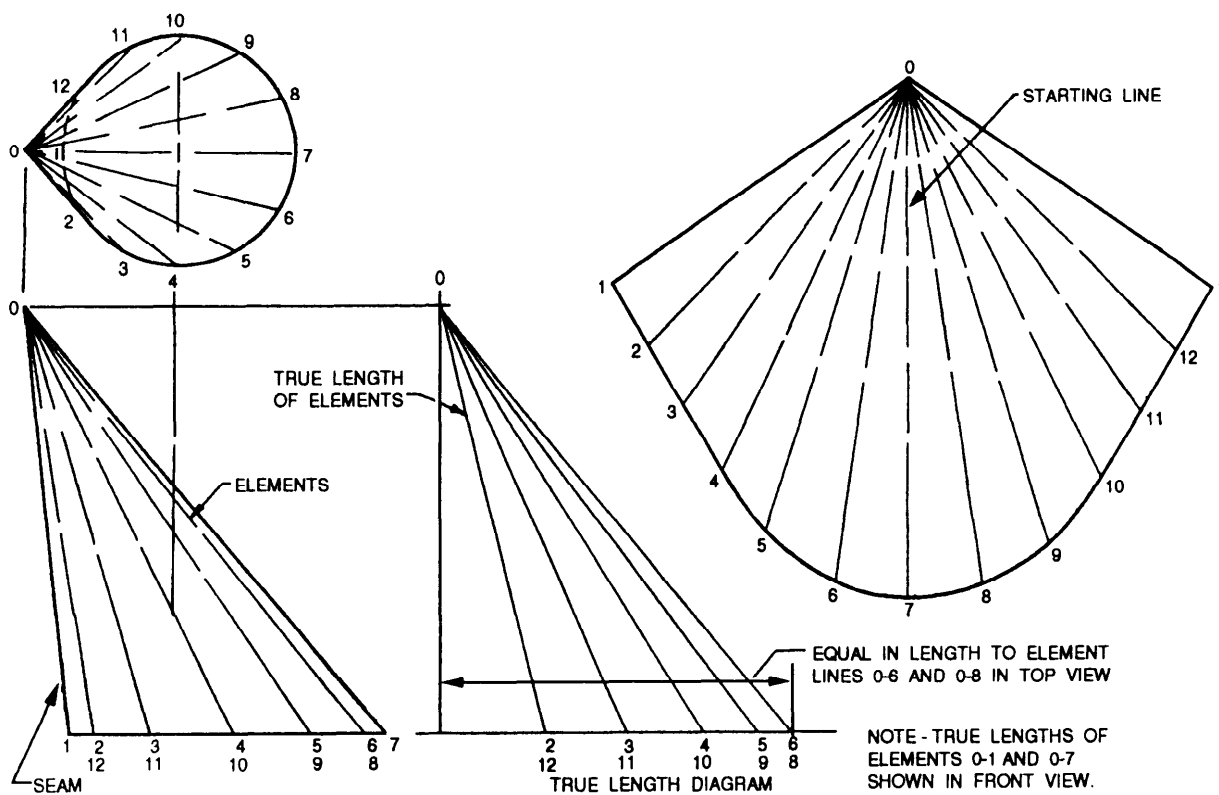NOTE - TRUE LENGTHS OF
ELEMENTS 0-1 AND 0-7
SHOWN IN FRONT VIEW.

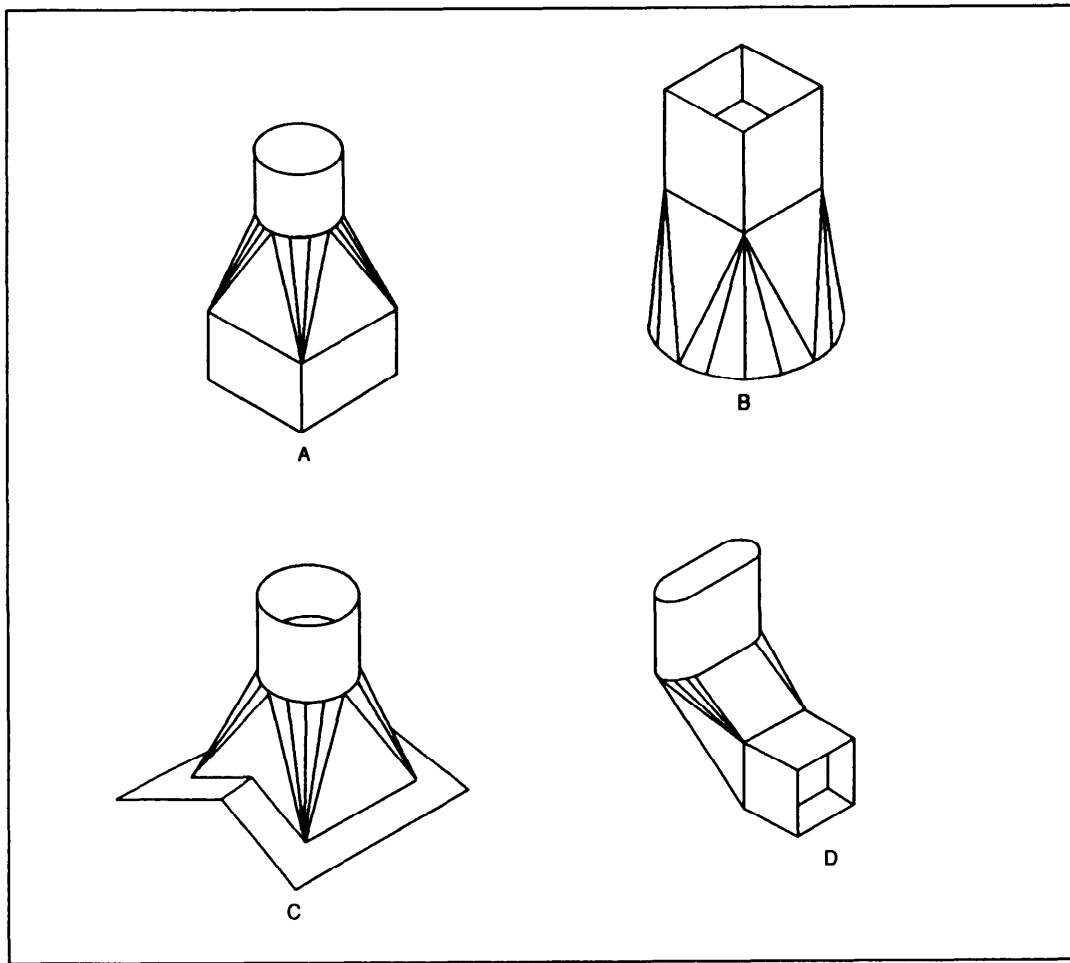Figure 8-16.—Development of an oblique cone.

Figure 8-17.—Transition pieces.

are not shown in either the top or front view, but would be equal in length to the hypotenuse of a right triangle, having one leg equal in length to the projected element in the top view and the other leg equal to the height of the projected element in the front view.

When it is necessary to find the true length of a number of edges, or elements, then a true-length diagram is drawn adjacent to the front view. This prevents the front view from being cluttered with lines.

Since the development of the oblique cone will be symmetrical, the starting line will be element 0-7. The development is constructed as follows: With 0 as center and the radius equal to the true length of element 0-6, draw an arc. With 7 as center and the radius equal to distance 6-7 in the top view, draw a second arc intersecting the first at point 6. Draw element 0-6 on the development. With 0 as center and the radius equal to

the true length of element 0-5, draw an arc. With 6 as center and the radius equal to distance 5-6 in the top view, draw a second arc intersecting the fast point 5. Draw element 0-5 on the development. This is repeated until all the element lines are located on the development view. This development does not show a seam allowance.

DEVELOPMENT OF TRANSITION PIECES

Transition pieces are usually made to connect two different forms, such as round pipes to square pipes. These transition pieces will usually fit the definition of a nondevelopable surface that must be developed by approximation. This is done by assuming the surface to be made from a series of triangular surfaces laid side-by-side to form the development. This form of development is known as triangulation (fig. 8-17).

Square to Round

The transition piece shown in figure 8-18 is used to connect round and square pipes. It can be seen from both the development and the pictorial drawings that the transition piece is made of four isosceles triangles, whose bases connect with the square duct, and four parts of an oblique cone having the circle as the base and the corners of the square pipe as the vertices. To make the development, a true-length diagram is drawn first. When the true length of line 1A is known, the four equal isosceles triangles can be developed After the triangle G-2-3 has been developed, the partial developments of the oblique cone are added until points D and K have been located Next the isosceles triangles D-1-2 and K-3-4 are added, then the partial cones, and, last, half of the isosceles triangle is placed at each side of the development.

Rectangular to Round

The transition piece shown in figure 8-19 is constructed in the same manner as the one previously developed except that all the elements are of different lengths. To avoid confusion, four true-length diagrams are drawn and the true-length lines are clearly labeled.

Connecting Two Circular Pipes

The following paragraphs discuss the developments used to connect two circular pipes with parallel and oblique joints.

PARALLEL JOINTS.—The development of the transition piece shown in figure 8-20 connecting two circular pipes is similar to the development of an oblique cone except that the cone is truncated The apex of the cone, 0, is located by drawing the two given pipe diameters in their proper position and extending the radial lines $1-1_1$ and $7-7_1$ to intersect at point 0. Fit the development is made to represent the complete development of the cone, and then the top portion is removed. Radius settings for distances $0-2_1$ and $0-3_1$ on the development are taken from the true-length diagram.
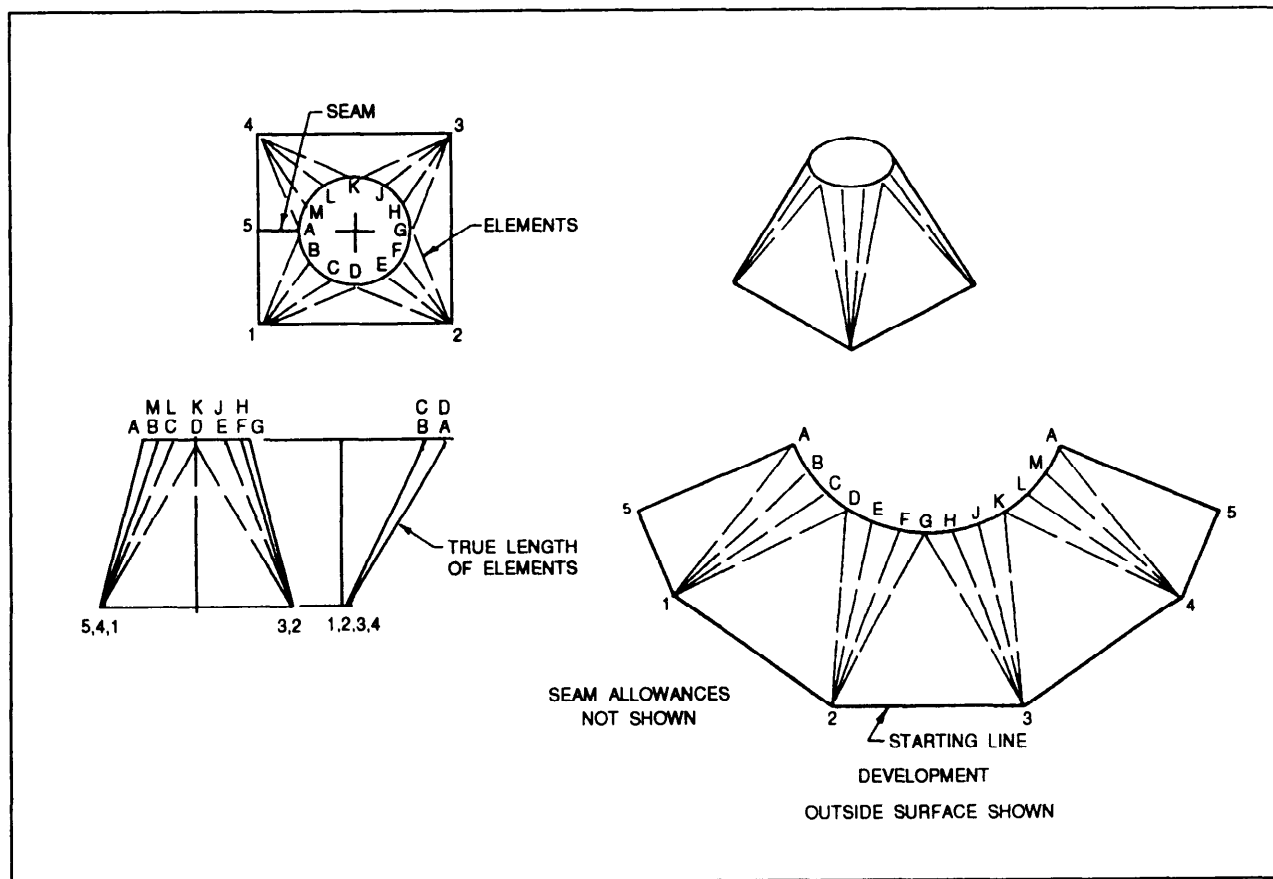

Figure 8-18.—Development of a transition piece—square to round.
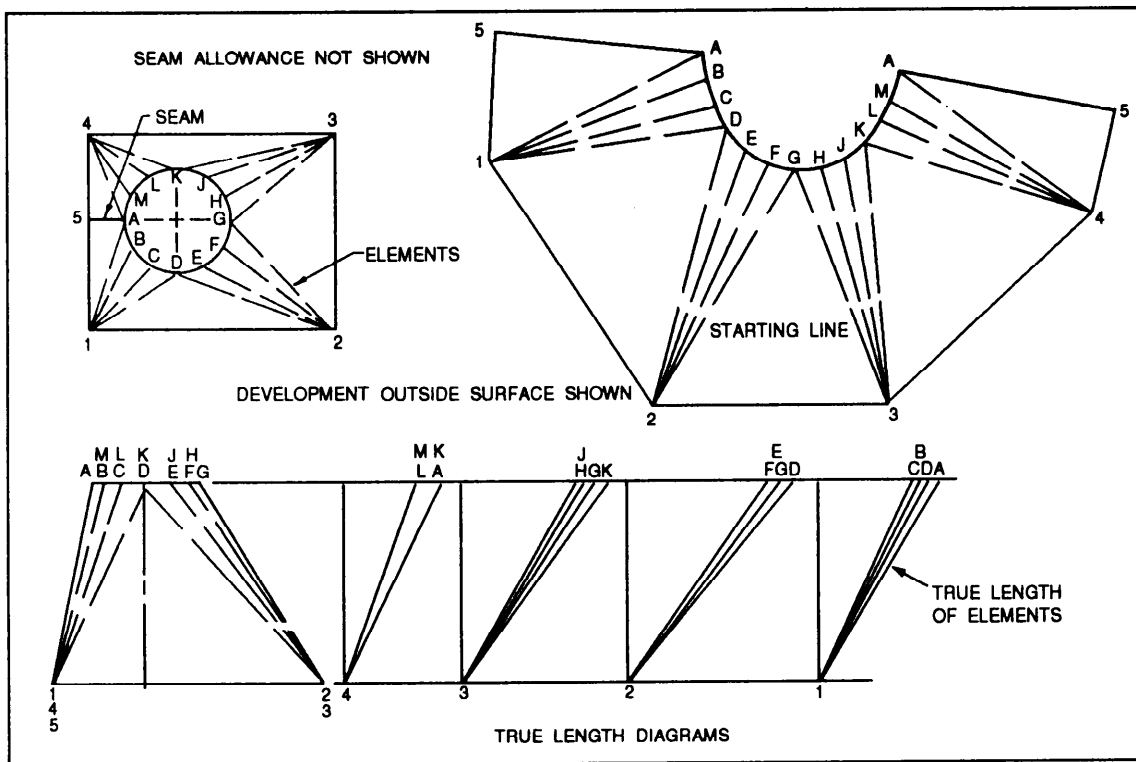
8-14

Figure 8-19.—Development of an offset transition piece— rectangular to round.
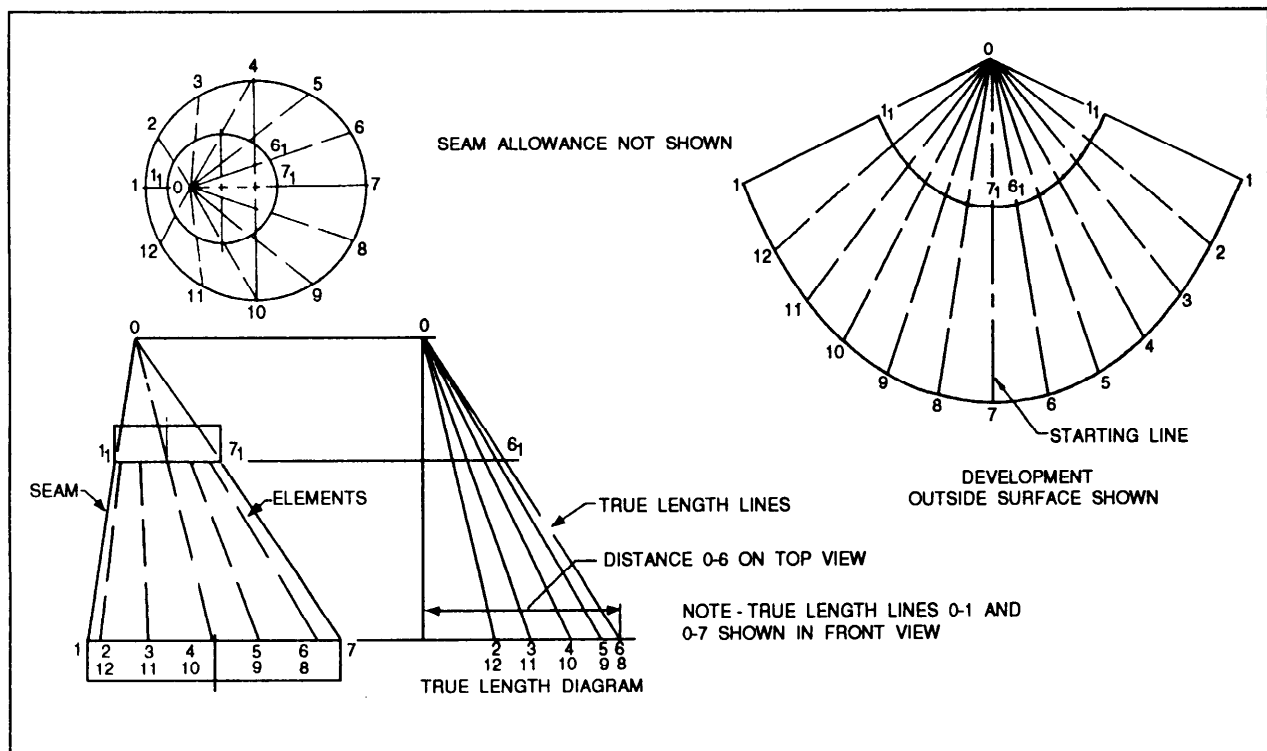

Figure 8-20.—Transition piece connecting two circular pipes—parallel joints

OBLIQUE JOINTS.—When the joints between the pipe and transition piece are not perpendicular to the pipe axis (fig. 8-21), then a transition piece should be developed. Since the top and bottom of the transition piece will be elliptical, a partial auxiliary view is required to find the true length of the chords between the end points of the elements. The development is then constructed in the same way as the development used to connect two circular pipes with parallel joints.
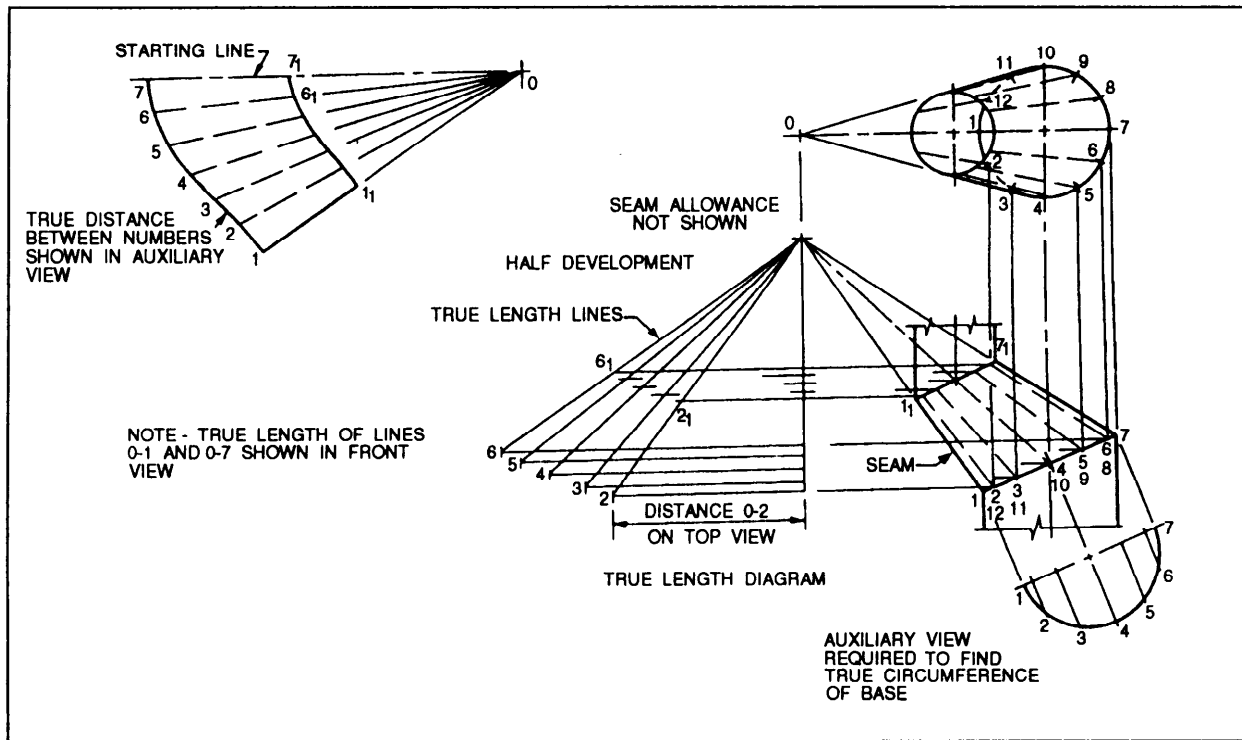

Figure 8-21.—Transition piece connecting two circular pipes—oblique joints.